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Abstract

REACTOR EXCURSION BEHAVIOR

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Because power excursions in nuclear reactors may, in extreme cases, conceivably result in plant damage and substantial fission-product release, the consideration of excursion behavior is an important aspect of overall safety evaluation of a power-reactor system. In making this evaluation, the inherent physical mechanisms in the reactor that act to quench or enhance the excursion must be identified, their behavior during the excursion established and their effect on excursion behavior understood. These factors, which are in part properties of the type of reactor system, are strongly influenced by specific design features. These must be carefully examined to ensure that undesirable effects are not introduced by design details, to evaluate possible means of initiating accidental excursions, and finally to establish certain specifications or control measures to apply to plant operation or to the design itself.

Much information relevant to the excursion aspect of power-reactor safety is now available from experimental excursion studies conducted under a variety of conditions with a number of different reactor systems, viz: TRIGA, a ZrH moderated system; Treat, which is graphite moderated; Kewb, an aqueous homogeneous system; Godiva, a fast all-metal assembly; Spert I, which is water-moderated with pin or plate type fuel; Spert II, which is heavy-water moderated with plate-type fuel; and Spert III, which is a high-pressure water-moderated system with plate-type fuel. It was demonstrated that various quenching mechanisms were effective in the self-limitation of deliberately induced power excursions; measurements of the magnitude of their reactivity effects were also obtained. These mechanisms were radiolytic gas production, geometric changes in fuel element configuration due to heating, density

changes in coolant-moderator by several heat-transfer mechanisms, changes in scattering cross-sections, Doppler effects and, in several cases, disassembly of the reactor. Most of these mechanisms are important in current power-reactor types; however, the magnitude of the reactivity effect is affected by the reactor type and even by the plant operating conditions (as was shown in experiments with Spert II and Spert III). As expected for these systems, increasing the initial temperatures and pressures in a test series resulted in significant, but not extreme, increase in the energy release. High coolant-flow rates also produced increases in energy release but not in fuel temperature. Most importantly, simulating power-reactor conditions did not significantly decrease the capability of these plants to safely self-limit excursions induced by reactivity insertions considerably in excess of prompt critical. The results with all systems show remarkable similarity in the way in which burst shape, peak power and energy vary with inserted reactivity and have remarkably simple mathematical descriptions. These features are not expected to be qualitatively different in power reactors. It is particularly important that, in the TRIGA, Treat and Spert I oxide-core experiments, the magnitude of the quenching effect and the details of burst behavior can be calculated directly from basic considerations.

The increase in excursion energy yield that occurred in the Spert I oxide-core tests with a fuel support system that permitted fuel rod bowing is an example of the influence that design details can have on reactor safety and suggests the possibility of using the effect to advantage.

Important differences and similarities were observed in the results of destructive test series with Spert I plate- and pin-type cores. Melting of 3% of the fuel plates in an excursion resulted in only minor transient pressure generation, whereas melting of 35% in the destructive test resulted in pressures of the order of several thousand lb/in.² with about 10% of the total energy release being attributable to chemical sources and of the order of not more than 3% appearing in mechanical form. The strong mechanical-disassembly effects did not contribute to the quenching of the power burst. In contrast, the rupture of fuel pins in the low-enrichment oxide core test resulted in strong quenching action that caused a change in the burst shape and limited the energy release. Despite the greater reactivity insertion and energy release, the mechanical effects were essentially negligible.